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INTERFACE REQUIREMENTS DOCUMENT (IRD)

FOR THE

GEOSTATIONARY OPERATIONAL ENVIRONMENTAL SATELLITE SERIES R (GOES-R) SYSTEM

SPACE SEGMENT (SS)
TO
SEARCH AND RESCUE (SAR) SERVICE

Document No.
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January 10, 2005

GOES-R PROJECT OFFICE
NASA GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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SPACE SEGMENT (SS) TO SEARCH AND RESCUE (SAR) SERVICE

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1.0 INTRODUCTION

The Geostationary Operational Satellite System Series R (GOES-R) is an operational mission planned to make observations from geostationary orbit. The GOES-R mission will provide an Advanced Baseline Imager (ABI), Hyperspectral Environmental Suite (HES), Space Environmental In-Situ Suite (SEISS), Solar Imaging Suite (SIS), and Geostationary Lightning Mapper (GLM). The items indicated below with bold titles, are covered in this IRD. The GOES R mission will also support the following communication data product services:

- GOES Rebroadcast (GRB) Service
- Low Rate Information Transmission (LRIT) Service
- Emergency Managers Weather Information Network (EMWIN) Service
- Data Collection System (DCS)
- **Search and Rescue (SAR) Service**

The five GOES-R mission segments that will interface and function to support the total GOES-R mission are described below.

- **Space Segment (SS)**
- Launch Support Segment (LSS)
- Ground Located - Command, Control, and Communications Segment (GL-C3S)
- Product Generation and Distribution Segment (PGDS)
- User Interface Segment (UIS)
- Archive and Access Segment (AAS)

1.1 Purpose

The purpose of this document is to describe and specify the functional and performance interface requirements for the communication links between the GOES-R Space Segment (SS) and the Search and Rescue (SAR) Service. This document it also intended to provide a basis for the subsequent development of an RF ICD between the satellite and the SAR ground segments by the spacecraft contractor.

1.2 Scope

The interface addressed in this document supports the exchange of data between the SS and the SAR ground segments. The SAR transponder in the GOES-R Series spacecraft (i.e., a component of the SS) performs a direct frequency translation of the uplink 406 MHz SAR RF band to a downlink L-Band band. Only those parameters which are necessary to specify the interface requirements will be referenced here; additional satellite transponder specifications will be contained in a satellite performance specification. This IRD therefore:

- Identifies required RF links between the SS and the SAR ground segments

- Establishes functional and performance requirements related to these links

1.3 Applicable Documents

The following documents of the issue listed, or of the issue in effect on the effective date of the contract, form a part of this IRD to the extent specified herein. In the event of a conflict between documents specified herein and other detailed content of this IRD, this IRD shall be the superseding requirement.

[1] Cospas-Sarsat, C/S T.001, Specification for Cospas-Sarsat 406 MHz Distress Beacons, Issue 3- Revision 6, October 2004

[2] Cospas-Sarsat, C/S G.003, Introduction to the Cospas-Sarsat System, Issue 5 – Revision 1, October 1999

[3] Cospas-Sarsat, C/S T.009, Cospas-Sarsat GEOLUT Performance Specification and Design Guidelines, Issue 1 - Revision 3, October 2004

[4] Cospas-Sarsat, C/S T.011, Description of the 406 MHz Payloads Used in the Cospas-Sarsat GEOSAR System, Issue 1 - Revision 4, October 2004

[5] Cospas-Sarsat, C/S T.013, Cospas-Sarsat Geosar Space Segment Commissioning Standard, Issue 1, October 2001

[6a] Cospas-Sarsat, C/S T.012, Cospas-Sarsat 406 MHz Frequency Management Plan, Issue 1, Revision 2 October 2004

[6b] Cospas-Sarsat, C/S T.012, Cospas-Sarsat 406 MHz Frequency Management Plan Annex D to End of Document, Issue 1 October 2002

[7] Cospas-Sarsat, C/S T.014, Frequency Requirements and Coordination Procedures, Issue 1, Revision 1 October 2004

[8] The Mission Requirements Document 2 (MRD-2B) for the GOES-R Series dated

December 13, 2004

[9] NOAA/NESDIS Antennas and RF System Capabilities Handbook, NOAA/OSD3-2001-0043R0UD0, 10 August 2001

[10] ITU Recommendation P.531-7 (2003), Ionospheric Propagation Data and Prediction Methods Required for the Design of Satellite Services and Systems

[11] ITU Recommendation P.581-2 (1990),The Concept of “Worst Month”

[12] ITU Recommendation P.618-8 (2003), Propagation Data and Prediction Methods Required for the Design of Earth-Space Telecommunication Systems

[13] ITU Recommendation P.676-5 (2001), Attenuation by Atmospheric Gases

[14] ITU Recommendation P.679-3 (2001), Propagation Data Required for the Design of Broadcasting-Satellite Systems

[15] ITU Recommendation P.837-4 (2003), Characteristics of Precipitation for Propagation Modeling

[16] ITU Recommendation P.838-2 (2003), Specific Attenuation Model for Rain for Use in Prediction Methods

[17] ITU Recommendation P.839-3 (2001), Rain Height Model for Prediction Methods

[18] ITU Recommendation P.841-3 (2003), Conversion of Annual Statistics to Worst-Month Statistics

[19] NTIA Manual of Regulation and Procedures for Federal Radio Frequency Management, May 2003 Edition, January 2004 Revision

[20] International Telecommunications Union (ITU) Recommendation ITU-R RA 769-1 of the 1998 Edition of the ITU Regulations for Radio Astronomy

[21] ITU Article S21 of the ITU Radio Regulations RR-S21 described in the 2001 Edition of the ITU Regulations for Power Flux Density Limits

[22] NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management, May 2003 Edition, September 2004 Revision

Discussion: The latest revisions of the SAR documents are available on the internet at http://www.cospas.sarsat.org Documents [1] through [7] contain information about the SAR Service and are applicable to the extent specified herein. In the event of conflict between this IRD and documents [1] through [7], this document shall take precedence.

The ITU documents described in items [10] thru [18] above can be used in determining propagation attenuation. ITU document [10] is for scintillation loss. The dash number used for each document is the updated release number. The web site for the ITU documents is http://www.itu.int/publibase/catalog/index.asp

1.4 Missing Requirements

This document contains all SAR RF interfaces except those labeled “TBD” and “TBR”. “TBD (To Be Determined) means that the contractor should determine the missing requirement in coordination with the government. The term “TBR” (To Be Reviewed) implies that the requirement is subject to review for appropriateness by the contractor or the government. The government may change “TBR” requirements in the course of the contract.

1.5 Definitions

The statements in this document are not of equal importance. The word “shall” designates a requirement. Any deviations from the requirements will require approval of the NASA contracting officer.

The word “will” designates a statement of fact about the system, its operational environment or the intent of the government

The word “threshold” is the minimum acceptable performance characteristic.

Rationale: MRD-2B, ID Item 1066

The word “goal” is an optimum level of performance, which, if met, could greatly enhance data utility.

Rationale: MRD-2B, ID Item 1067

2.0 SEARCH AND RESCUE (SAR) SERVICE AND INTERFACE DESCRIPTION

2.1 General Description

The GOES support to the Search and Rescue (SAR) service is provided by GOES satellites located at 75º and 135º [TBR] W. Longitude. Each satellite employs an earth coverage antenna for reception of the uplink SAR UHF beacon signals and another earth coverage antenna to provide a downlink L-Band relay to the ground supporting LUT terminals. Both the beacons and the LUTs may be anywhere in the earth coverage area of the satellite out to a design minimum elevation angle of 5º.

The SAR subsystem onboard each GOES satellite is a dedicated transponder that receives UHF distress signals broadcast by:

- Emergency Locator Transmitters (ELTs) carried on aircraft,
- Emergency Position Indicating Radio Beacons (EPIRBs) aboard marine vessels,
- Personal Locator Beacons (PLB) used in land-based applications
- System Beacons used for calibration and performance monitoring.
- Ship Security Alerting System (SSAS) beacons

The beacons are channelized in an allocated 100 kHz bandwidth as described in Section 3.2. Within the GOES SS, this entire uplink SAR bandwidth is frequency translated to L-Band and downlinked to a Cospas-Sarsat LUT ground terminal. These ground terminals are referred to as Geostationary Earth Orbit Local User Terminals (GEOLUTs). In this document, where there is no possibility of ambiguity with Low Earth Orbit Local User Terminals (LEOLUTs), they will be referred to simply as Local User Terminals (LUTs).

3.0 SAR RF INTERFACE REQUIREMENTS

3.1 General

The SAR data link requirements summary is described in Table 3.1-1.

3.1.1 Introduction and Functional Elements

As indicated in Section 2.1, the SAR 406 MHz Distress Beacons include five implementations: ELT, EPIRB, PLB, SSAS, and System Beacons (used for calibration

and performance monitoring). Each of these includes a Digital Message Generator, a Modulator, and a 406 MHz transmitter. Only those elements necessary for specifying the SS-to-SAR interface will be addressed here. Additional information is available in [1] and [2].

SAR Uplink Tx	**Requirement**	**Rationale**
Worst case EIRP (dBm)	30	See item 1 in para. 6.1
Freq. band allocation (kHz)	406.000 – 406.100	ITU RR 5.266, MRD-2B, ID Item 4452
Polarization	Either Linear N-S or RHC	Applicable Doc. [1]
Tx Data Rate (bit/s)	400	ID item 4447 in MRD-2B
Format	Bi-Phase-L	C/S T.001, para 2.3.5
Modulation (radians)	PM on carrier MI=±1.1 ± 0.1	C/S T.001, para. 2.3.6
FEC	As present on beacon signal	
Satellite Rx		
Polarization	RHC	C/S T.001
Coverage	Earth coverage to antenna with 5 deg. elevation angle	ID item 4454 in MRD-2B
G/T (dB/K)	-14 at edge of coverage	SAR working group
Dynamic Range (dBm)	Below noise to -125	Heritage spec. from GOES-N,O,P
Axial ratio (dB)	≤ 3	
Satellite Tx		
Center Frequency (MHz)	1544.500	ITU Radio Reg. Article 5.356, and MRD-2B ID Item 4453
Bandwidth (kHz)	Approx. 100	ID Item 4451 in MRD-2B
Polarization	RHC	Minimize interference with LHCP used with POES satellite downlink frequency.
EIRP (dBm)	45	Heritage spec. from GOES-N,O,P
Coverage	Earth coverage to antenna with 5 degree elevation angle	ID item 4455 in MRD-2B
Axial ratio	Para. 5.2.1	
BER	Para. 6.2	
Ground LUT Rx Terminal		
Polarization	RHC	SAR working Group
Axial ratio	≤ 2 dB	
Min. Rx G/T (dB/K)	11	SAR working Group
Rx System Loss (dB)	2.0	Heritage spec. from GOES-N,O,P

Table 3.1-1 SAR Data Link Requirements Summary

3.2 SAR Uplink Transmit Interface

3.2.1 Frequency Channelization

The beacon uplink frequencies are one of 19 channels, each of 3 kHz bandwidth, with center frequencies ranging from 406.022 MHz to 406.076 MHz.

Rationale: The channel center frequencies are described in Table H-2 of [6]. The 406.000—406.100 band is limited to use by the satellite emergency position-indicating radio beacons in accordance with ITU Radio regulations, Article 5.266.

3.2.2 Frequency Accuracy and Long-Term Stability

The carrier frequency accuracy of beacons operating in the 406.025 MHz channel will be set at +/- 2 kHz. The carrier frequency will not vary more than +/- 5 kHz from 406.025 MHz in 5 years.

The carrier frequency accuracy of beacons operating in the 406.028 MHz channel will be set at +/- 1 kHz. The carrier frequency will not vary more than + 2 kHz/-5 kHz from 406.028 MHz in 5 years.

All beacons operating in other channels as defined by C/S T.012 will have a carrier frequency accuracy of +/- 1 kHz , and will not vary more than +/- 5 kHz from that channel center frequency in 5 years.

Rationale: The specifications indicated above are described in reference document [2] titled Cospas-Sarsat, C/S T.001, Specification for Cospas-Sarsat 406 MHz Distress Beacons.

3.2.3 Short-Term Frequency Stability

The beacon short-term frequency stability is specified as ≤ 2 parts in 10^9 over 100 ms.

3.2.4 Beacon Transmit Polarization

The vast majority of beacons are implemented with linear polarization. For link budget calculations, a worst-case polarization mismatch corresponding to a linearly polarized beacon antenna and a RHCP satellite receive antenna shall be assumed.

4.0 LOCAL USER TERMINAL (LUT) REQUIRMENTS

4.1 General

The LUTs are L-Band receive-only terminals.

4.2 Demodulation

The LUT will be capable of bi-phase demodulation of the received beacons. Baseband processing of the received data signal is described in [3].

5.0 SPACE SEGMENT (SS) REQUIREMENTS

5.1 General

The Space Segment (SS) requirements consist of receiving the uplink 100 kHz wide 406 MHz beacon frequency band, and then frequency translating to an equivalent bandwidth in L-Band, amplifying, and transmitting this signal to the ground station LUT.

Rationale: ID item 4445 in the MRD-2B document requires the downlink to the LUT to be a direct frequency translation of the uplink band.

5.2 Satellite-to-LUT Downlink Interface

5.2.1 Transmit Antenna Axial Ratio

The satellite transmit antenna axial ratio shall not exceed 1 dB.

Rationale: Recommendation by Comm. working group. Measured value for GOES-N was 0.6 dB.

5.2.2 Radio Astronomy Band Protection

The EIRP value for the SAR downlink shall protect the radio astronomy band from 1660 to 1670 MHz, so that the spectral power flux density in this band at surface of the earth shall be $\leq$ -266 dB W/m^2-Hz.

Rationale: Compliance is required with the power flux density requirement for the Radio Astronomy Band as described in the International Telecommunications Union (ITU) Recommendation ITU-R RA 769-1. The ITU specifies a maximum PFD at the ground of -251 dBW/m^2/Hz for the RA band, and this level must be reduced by another 15 dB for geostationary satellites.

5.3 Unwanted Radiation Mask

All communication links must comply with paragraph 5.2.2, for frequencies less than 470 MHz and 5.6.2 for frequencies above 470 MHz, of the NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management, May 2003 Edition, September 2004 Edition.

6.0 LINK PERFORMANCE SPECIFICATION

Based on the assumed link parameters of Section 6.1, the link performance shall meet the performance criteria of Sections 6.2. Performance is specified for the combined up and downlinks, i.e., for the full path between beacon and LUT.

6.1 Assumed Link Parameters

The following conditions shall be assumed in the calculation of expected link performance.

1. The worst-case effective beacon EIRP of 30 dBm shall be assumed.

   Rationale: This follows from a beacon power output of 35 dBm (i.e., nominal 37 dBm – 2 dB), followed by a worst-case antenna gain (-3 dBm), followed by an additional 2 dB loss for antenna orientation. It is recognized that absolute worst case scenarios could result in worse values.

   Propagation impairments of 0.2 dB on the uplink (406 MHz) and 0.5 dB on the downlink (1544 MHz) shall be assumed.

2. Elevation angles at both the beacon and the LUT shall be assumed the worst-case value of 5º.

   Rationale: Earth coverage requirements described above is a flow-down requirement from ID items 4454 and 4455 in the MRD-2A Document.

3. Worst case polarization mismatches on the uplink and downlink shall be assumed. The uplink polarization loss will be 4.1 dB and the downlink worst case polarization loss will be 0.2 dB.

   Rationale: C/S T.014

4. Interference accesses shall be assumed to be small and no specific entry is required.

5. The following gains and losses shall be assumed: (a) a modulation loss due to non-orthogonal PSK of 1 dB [TBR], (b) a BCH coding gain of zero dB and (c) an integration gain (from multiple messages) of 7 dB.

   Rationale: The Cospas-Sarsat is now using an integration gain of 7 dB as described in C/S T.014 Annex H.

6.2 Link Bit Error Rate

The end-to-end link bit error rate (BER) shall be $1 \cdot 10^{-5}$ at 99.9 % availability, worst month or better under the worst-case assumptions of Section 6.1.

Rationale: Heritage specification requirement from GOES-N,O,P Program.

6.3 Communications Link Budget Requirement

The spacecraft contractor shall provide the communication link budgets in the ICD for the SAR data links.

Changes to the link Budget shall be documented and reported monthly to the GSFC Communications Subsystem Manager.

Rationale: There is a need to ensure adequate link margin prior to and following the manufacturing of flight hardware.

APPENDIX A – ABBREVIATIONS AND ACRONYMS

ALC	Automatic Level Control
AM	Amplitude Modulation
AS	Archive Segment
β	Modulation Index
BCH	Bose-Chaudhuri-Hocquenghem (Forward Error Correction Code)
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
BW	Bandwidth or Beamwidth (context dependent)
C3S	Command, Control and Communications Segment
CDA	Command and Data Acquisition
CDAS	Command and Data Acquisition Station
CCSDS	Consultative Committee on Space Data Systems
C/N_0	Carrier to Noise Density Ratio (dB-Hz)
COSPAS	(Russian: Cosmicheskaya Sistyema Poiska Avariynich Sudov) Space System for the Search of Vessels in Distress
CP	Circularly Polarized or Circular Polarization
CWG	Communications Working Group
EIRP	Equivalent Isotropically Radiated Power
ELT	Emergency Locator Transmitter
EMWIN	Emergency Managers Weather Information Network
EPIRB	Emergency Position Indicating Radio Beacons
GEOLUT	Geostationary Local User Terminal
GMS	Geostationary Meteorological Satellite
GOES	Geostationary Operational Environmental Satellite
GRB	GOES Rebroadcast
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
G/T	Gain-to-Noise Temperature Ratio (dB/K)
ICD	Interface Control Document
IRD	Interface Requirements Document
ITU	International Telecommunications Union
L-Band	1.0 – 2.0 GHz Frequency Band
LEO	Low Earth Orbit
LHCP	Left Hand Circularly Polarized
LP	Linearly Polarized or Linear Polarization
LRIT	Low Rate Information Transmission

LSS	Launch Support Segment
LUT	Local User Terminal
MCC	Cospas-Sarsat Mission Control Center
Meteosat	Meteorological Satellite
NASA	National Aeronautics and Space Administration
NOAA	National Oceanographic and Atmospheric Administration
PDR	Preliminary Design Review
PFD	Power Flux Density
PGDS	Product Generation and Distribution Segment
PLB	Personal Locator Beacon
PM	Phase Modulation
POES	Polar Operational Environmental Satellite
PSK	Phase Shift Keying
RA	Radio Astronomy
RF	Radio Frequency
RHCP	Right Hand Circularly Polarized
RVTM	Requirements Verification Traceability Matrix
SAR	Search and Rescue
SARSAT	Search and Rescue Satellite-Aided Tracking
S-Band	2.0 – 3.0 GHz Frequency Band
SEISS	Solar Environment In-Situ Suite
SIS	Solar Imaging Suite
SS	Space Segment
SSAS	Ship Security Alerting System
TBD	To Be Determined
TBR	To Be Reviewed
TBS	To Be Supplied
TRD	Technical Requirements Document
UHF	300 – 1000 MHz Frequency Band
UIS	User Interface Segment
USG	United States Government
X-Band	8.0 – 12.0 Frequency Band (IEEE). In this document, X-Band is taken to include 7.25 – 8.40 GHZ.